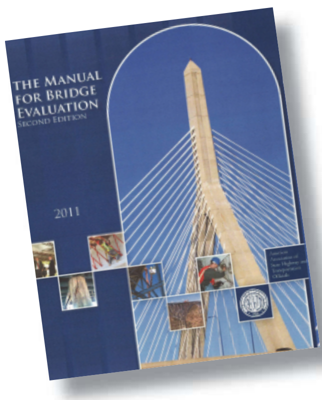
Load Rating Concrete Bridges: Part 1

by Dr. Dennis R. Mertz



The American Association of State Highway and Transportation Officials (AASHTO) Subcommittee on Bridges and Structures (SCOBS) adopted the load and resistance factor rating (LRFR) bridge-evaluation methodology as an acceptable load rating procedure in the first edition of the AASHTO *Manual for Bridge Evaluation* (MBE) in 2005. The MBE includes the probability-based, calibrated LRFR method along with the more traditional, uncalibrated strength-based load factor rating (LFR) method. The LRFR method includes rating for both the traditional strength and newer service limit states.

The Federal Highway Administration (FHWA) mandates that LRFR be used for bridges designed by the *AASHTO LRFD Bridge Design Specifications* using HL-93, after October 1, 2010. For other bridges, the LRFR or LFR methods are allowed. Nonetheless, the calibrated LRFR methodology yields more reliable load ratings in all cases, though not uniformly higher nor lower ratings.

The LRFR rating method in Part A of Section 6 of the MBE consists of three rating levels: design, legal, and permit load rating. Design load rating uses the HL-93 live-load model and provides a comparison to today's design standard. The design load rating is not used for operational decisions but only for reporting to the National Bridge Inventory (NBI). Legal load rating uses the bridge owner's legal loads as the live-load models and provides ratings to make load posting, bridge replacement, and rehabilitation decisions. Finally, permit load rating uses the candidate permit loads and provides ratings to make permit-issuing decisions.

The LRFR bridge-evaluation methodology considers both strength and service limit states. The strength limit states—Strength I for design and legal load rating and Strength II for permit load rating—are required for all bridges (see Table 6A.4.2.2-1 in the MBE). Several concrete-bridge specific limit states are included in the three levels of LRFR bridge evaluation. The material-specific limit states are service limit states with most of them being optional.

LRFR for concrete members includes two new service limit states. At the design load rating level, prestressed concrete members are required to be rated using the Service III limit state, which controls cracking just as in the *AASHTO LRFD Bridge Design Specifications*. At the legal load rating level, the Service III limit state becomes optional for prestressed concrete members. At the permit load rating level, the Service I limit state is optional for both prestressed and reinforced concrete members, and guards against yielding of the reinforcement and permanently open cracks in the concrete.

The new service limit states in LRFR are not only limited to concrete structures. The Service II limit state, which controls yielding of the steel members and permanent deformation, just as in the *AASHTO LRFD Bridge Design Specifications*, is required at the design load rating level and the legal load rating level, but is optional at the permit load rating level for steel members.

All of the service limit states were deemed necessary by the developers of the LRFR bridge-evaluation methodology to protect bridges and allow no damage under both legal and permit loads. AASHTO SCOBS, however, decided to allow the individual bridge owners to decide if the optional service limit states would be applied in their jurisdictions. If applied, these optional service limit states would result in less damage to bridges, but more posted bridges and fewer issued permits.

EDITOR'S NOTE

If you would like to have a specific provision of the AASHTO LRFD Bridge Design Specifications *explained in this series of articles, please contact us at www.aspirebridge.org.*

Special Notice

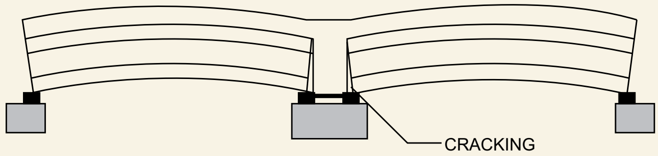
BRIDGES COMPOSED OF SIMPLE-SPAN, PRECAST CONCRETE GIRDERS MADE CONTINUOUS

This Special Notice explains Article 5.14.1.4—Bridges Composed of Simple Span Precast Girders Made Continuous (also known as Continuous for Live Load Bridges). As the name states, these bridges are made by erecting single-span, precast concrete girders and then connecting them over the supports with a cast-in-place concrete diaphragm and deck slab to establish full-depth positive and negative moment connections. The girders carry their own dead load and the slab dead load as simple spans, but all subsequent loads are carried as continuous spans. Deck reinforcement provides the negative moment resistance.

The drawback to this design is that the girders will camber upward due to creep and shrinkage. In contrast, differential shrinkage between the deck and the girders causes the giders to deflect downward. Temperature gradients also affect the camber. If the net camber is positive, a positive moment develops and the connection cracks, as shown in the figure. For this reason, Article 5.14.1.4.9 requires a positive moment connection at the joint.

An analytical study in NCHRP Report 322[1] suggested that any positive moment cracking at the joint resulted in a loss of continuity because the crack has to close for continuous beam behavior to occur. However, experimental work reported in NCHRP 519[2] and confirmed by others[3] showed this is not necessarily true. Cracks in concrete, even at cold joints, are jagged and aggregate interlock provides frictional forces. Thus, the connection can tolerate some cracking and still provide continuity.

When NCHRP 519 was published, Article 5.14.1.4 contained a provision stating that the connection could be considered continuous if the net stress at the bottom of the diaphragm from superimposed permanent loads, settlement, creep, shrinkage, temperature gradient, and 50% of live load was compressive. Because this was already in the



American Association of State Highway and Transportation Officials (AASHTO) *LRFD Bridge Design Specifications* and it was consistent with the experimental results showing the connection could tolerate some cracking, the provision was retained as Article 5.14.1.4.5.

Given that calculation of the diaphragm stresses is complex, there was a desire for a simple rule. At the time, the Tennessee Department of Transportation had a provision requiring the girders be aged 90 days before continuity was established. This was adopted as Article 5.14.1.4.4, which requires that the engineer provide a positive moment connection with a strength of 1.2 M_{cr} and specify in the contract documents that the girders are to be at least 90 days old when continuity is established.

The reasoning given in the commentary is that by 90 days, 60% of the creep and 70% of the shrinkage in the girder is theoretically gone. The behavior of the system will be dominated by differential shrinkage of the deck so the possibility of positive moment cracking significant enough to affect continuity is very low.

In effect, the provisions and commentary of Article 5.14.1.4 give the designer four options:

1) Provide a positive moment connection with a strength of 1.2 M_{cr} and require the girders to be at least 90 days old at the time continuity is established. Experience in Tennessee shows there is no reason to specify a minimum age longer than 90 days unless some unusual situation suggests that significant upward camber may occur after 90 days.
2) Provide a positive moment connection with a strength of 1.2 M_{cr} and use the provisions of Article 5.4.2.3, with k_{td} = 0.7, to establish the minimum age at which continuity can be established (commentary).
3) Use the provisions of Article 5.14.1.4.5 and consider the bridge continuous if the net stress at the bottom of the diaphragm from superimposed permanent loads, settlement, creep, shrinkage, temperature gradient, and 50% of live load is compressive.
4) Calculate the actual restraint moments and determine the degree of continuity from the analysis (Article 5.14.1.4.2).

If the connection does not provide full continuity, the effect of partial continuity must be considered as required in Article 5.14.1.4.5.

References

1. Oesterle, R. G., J. D. Glikin, and S. C. Larson. 1989. *Design of Precast-Prestressed Bridge Girders Made Continuous*, National Cooperative Highway Research Program Report 322, Transportation Research Board, National Research Council, Washington, DC.
2. Miller, R. A., R. Castrodale, A. Mirmiran, and M. Hastak. 2004. *Connection of Simple-Span Precast Concrete Girders for Continuity*, National Cooperative Highway Research Program Report 519, Transportation Research Board, National Research Council, Washington, DC.
3. Newhouse, C. D., C. L. Roberts-Wollman, and T. E. Cousins. 2007. "Comparison of Strands and Bars for Positive Moment Connection of Continuous Precast Concrete Bulb-Tee Girders," *PCI Journal*, May/June.

The editors of ASPIRE™ thank J. P. Benard, chief engineer with Bayshore Concrete Products, for raising the topic. In addition, the editors thank Dr. Richard A. Miller of the University of Cincinnati for preparing this explanation and Dr. Dennis Mertz and Dr. Carin Roberts-Wollman of Virginia Tech for their input.